REM WORKING PAPER SERIES

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REM Working Paper 0388-2025

July 2025

REM – Research in Economics and Mathematics
Rua Miguel Lúpi 20,
1249-078 Lisboa,
Portugal

ISSN 2184-108X

Fundação para a Ciência e a Tecnologia
U LISBOA | UNIVERSIDADE DE LISBOA
ISEG Lisbon School of Economics & Management Universidade de Lisboa
REM RESEARCH IN ECONOMICS AND MATHEMATICS

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Functional public sector spending and SDGs: an efficiency map for the EU countries*

António Afonso* **José Alves†** **Najat Bazah‡** **A. J. Sánchez-Fuentes§**

July 2025

Abstract

We evaluate the efficiency of public expenditure in the 27 European countries in achieving the Sustainable Development Goals (SDGs) of the 2030 Agenda. Using Data Envelopment Analysis (DEA), we map performance over the period 1995-2023, incorporating Musgravian functional spending – *redistribution*, *allocation*, *public services*, and *private activities* – as input variables, and constructing synthetic indices for the five pillars of the 2030 Agenda – *people*, *planet*, *prosperity*, *peace*, and *partnership* – as outputs. Results indicate that input efficiency scores range from 0.77 to 0.95, while output scores range from 0.88 to 0.93, suggesting a potential 5%-23.5% increase in inputs or a 7%-11.7% improvement in outputs. Denmark, Ireland, and Finland are efficient throughout the entire period, with strategic reductions in public spending correlating with high SDG performance. Sweden also has high efficiency and leads in multiple pillars by 2023. Conversely, the peace pillar remains the least achieved, while the people pillar shows the greatest progress.

JEL classification: C61; H11; H72; O57; Q56
Keywords: public spending; Sustainable Development Goals (SDGs); Data Envelopment Analysis (DEA); government spending efficiency

* We thanks participants at the 13th UECE Conference in Economic and Financial Adjustments (Lisbon, 2025) for very useful comments. This work was supported by the FCT (*Fundação para a Ciência e a Tecnologia*). The opinions expressed herein are those of the authors and do not necessarily reflect those of the authors' employers. Any remaining errors are the authors' sole responsibility.
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1. Introduction

In recent years, the analysis of public sector efficiency has gained increasing relevance, particularly in the context of achieving the Sustainable Development Goals (SDGs) established by the United Nations in 2015 and framed within the 2030 Agenda.[1] Nevertheless, although numerous studies have addressed efficiency in the public sector, only a limited number have explicitly linked their analysis to the achievement of the SDGs. Moreover, the current global governance, with a recent very important decrease in the total volume of development funds, leads to the higher opportunity costs for the allocation of these resources and, consequently, to the necessity of optimizing the level of achievement.

This global agenda is structured around five fundamental pillars: *people*, *planet*, *prosperity*, *peace*, and *partnership*, which encompass the 17 SDGs and their 169 specific targets. Given that governments are key actors in implementing policies that drive the attainment of these goals, it becomes essential to assess whether public expenditure is being used efficiently and in alignment with sustainability commitments.

Against this backdrop, the primary objective of this study is to evaluate the efficiency of the public sector in the 27 European Union countries in relation to the achievement of the SDGs, using a Data Envelopment Analysis (DEA) approach. To this end, we adopt Musgravian classification of public spending as input variables – *redistribution*, *allocation*, *public services*, and *private activities* – and construct synthetic performance indices for the five pillars of the 2030 Agenda as output variables. These outputs are normalized based on the relative weights of each goal within the SDG framework. This approach not only identifies which countries are achieving better sustainability outcomes but also reveals how efficiently they are utilizing public resources to do so. Moreover, the analysis spans a broad period (1995-2023), allowing us to map observed patterns of evolution, sustained efficiency, or structural lags.

Therefore, and making use of different combinations of the public expenditure, as inputs, and the five pillars of the 2030 Agenda, as outputs, we developed several DEA models

[1] The 17 SDGs are: 1) No poverty, 2) Zero hunger; 3) Good health and well-being; 4) Quality education; 5) Gender equality; 6) Clean water and sanitation; 7) Affordable and clean energy; 8) Decent work and economic growth; 9) Industry, Innovation, Technology and Infrastructure; 10) Reduced inequality; 11) Sustainable cities and communities; 12) Responsible consumption and production; 13) Climate action; 14) Life below water; 15) Life on land; 16) Peace, justice and strong institutions; 17) Partnerships for the goals. For more information on SDGs at https://sdgs.un.org/goals

combinations to assess the efficiency of government spending to ensure a sustainable growth pact proxied by the pillars. Our results show that, for instance, with input efficiency scores ranging between 0.77 and 0.95, public inputs could decrease by 5% to 23.5% while maintaining the same level of outputs. Conversely, with output efficiency scores between 0.88 and 0.93, outputs could increase by 7% to 11.7% while keeping the same level of inputs.

The results also reveal that Denmark, Finland and Ireland reduced its public spending across all categories considered. These three countries are those that show the highest levels of SDG achievement. Lastly, Sweden reduced its public spending in all categories except private activities.

Furthermore, after computing the DEA models, we found that Denmark, Ireland, and Finland are efficient throughout the entire period (1995-2023). Bulgaria, Cyprus, Estonia, Luxembourg, and Romania show efficiency for the period 1995-2013. Sweden is efficient during the 2004-2023 period.

In short, there are significant differences in public expenditure efficiency across EU-27 countries with respect to SDG achievement. Countries exhibiting higher levels of efficiency in the use of public resources tend to show better performance across the 2030 Agenda pillars. Selective and strategic reductions in public spending in certain functions may be associated with higher efficiency and greater progress toward meeting the SDGs.

The article is structured as follows: section 2 provides a literature review on the SDGs and public expenditure efficiency; section 3 presents the methodology used; section 4 reports the results of the empirical analysis; and finally, section 5 is the conclusion.

2. Literature review

2.1. SDGs and pillars

The 2030 Agenda, adopted by the United Nations in 2015, is a comprehensive action plan for people, planet, and prosperity. It is structured around 17 Sustainable Development Goals (SDGs), 169 targets, and five key pillars: *people*, *planet*, *prosperity*, *peace*, and *partnership* (United Nations, 2020).

Since its formal adoption, there has been growing interest in research focused on the progress and achievement of the SDGs (Lomazzi et al., 2014; Bali Swain and Yang-Wallentin, 2020; Eurostat, 2023). For instance, the United Nations publishes an annual SDGs report (the

most recent being from 2024, by the Department of Economic and Social Affairs) that presents updated data on the SDG progress of its member states. Among the highlighted figures, the percentage of people living on $1.90 per day or less increased dramatically following the 2020 pandemic crisis – from 16% in 2019 to 47% in 2020. In terms of health and well-being, the situation is particularly alarming: between 2020 and 2021, 15 million deaths were recorded, along with a rise in mental health disorders such as anxiety and depression. The gender gap in labor force participation also persists, with women still significantly underrepresented in leadership positions. Environmental issues remain critical, further exacerbated by the ongoing challenges of climate change.

Bali Swain and Yang-Wallentin (2020) indicate that in developed countries, all three SDG dimensions – environmental, social, and economic – are important for sustainable development, though the social and environmental dimensions drive the most substantial development gains. In developing countries, the environmental dimension contributes less in relative terms, but it remains important in the short term due to the synergies and trade-offs among the three dimensions. Similarly, Mutiarani and Siswantoro (2020) find that factors such as regional size and local own-source revenues influence SDG performance levels.

At the European level, several studies have evaluated the degree of SDG achievement (Vila et al., 2021; Barberà-Mariné et al., 2024). Onrubia et al. (2022) examine disparities among European countries by constructing composite SDG indices, showing that the greatest divergences occur between countries with higher GDP per capita and those in Eastern and Southern Europe. The most significant differences are observed in areas such as income inequality, gender equality, education, partnerships, peace, justice and institutions, responsible consumption and production, and industry, innovation and infrastructure.

Other research has proposed different classifications of the SDGs. Based on the dimensions and pillars originally established by the United Nations (2015a, 2015b), various studies have categorized the SDGs according to these pillars for implementation purposes (Tremblay et al., 2020; Rochström and Sukhdev, 2016; IAEG-SDGs, 2022; Government of Ireland, 2023, among others).

Numerous studies have also analyzed the synergies and trade-offs among the SDGs (Cristóbal et al., 2021; Warchold et al., 2021; Tsagarakis et al., 2024). Le Blanc (2015) and Pradhan et al. (2017) conceptualize the SDGs as a network of interconnected targets, excluding

those related to means of implementation (SDG 17). Certain thematic areas are strongly interlinked – for example, SDGs 1, 8, 10, and 12 are each connected with at least 10 other goals – while others are less integrated, such as SDGs 7, 9, and 14.

Nodehi et al. (2022) and Taghvaee et al. (2023) study the interrelations among the three SDG dimensions across regions such as East Asia and the Pacific, North Africa, and North America, using econometric techniques including Simultaneous Equation Systems, Vector Autoregressive models, and Granger Causality analyses covering the period 1971–2016. Dawes et al. (2022) provide a detailed analysis of target-level interlinkages using the Institute for Global Environmental Strategies (IGES) SDG Interlinkages Tool, finding that goals 1 to 3 are more likely to be achieved compared to environmentally oriented goals (13 to 15).

Manandhar et al. (2018) explore the interactions between goals 3 and 5 and the remaining 13 goals that influence health outcomes. They find that goal 4 significantly affects both goals 3 and 5, while decent work (goal 8) influences occupational morbidity and mortality for both men and women. Lawrence et al. (2020) demonstrate the interlinkages between goal 4 and seven other goals (3, 8, 12, 13, 14, 16, and 17), all of which have targets directly related to education or skills development. Lastly, Fuso Nerini et al. (2018) examine the connections between goal 7 and other goals, identifying synergies and trade-offs in three core areas: improving welfare and well-being, developing physical and social infrastructures for sustainable growth, and ensuring sustainable natural resource management.

2.2. Government spending efficiency

The efficiency of the public sector has emerged as a topic of significant academic interest (Madden et al., 1997; Afonso et al., 2005; Afonso et al., 2009). Numerous studies have assessed public sector efficiency using various methodological approaches. Among parametric methods, Stochastic Frontier Analysis (SFA) has been widely employed (Mayston, 2015; Radulovic and Dragutinović, 2015). On the non-parametric side, two common approaches are Data Envelopment Analysis (DEA) (Ruggiero, 1996; Husain et al., 2000) and Free Disposal Hull (FDH) (Kirana and Saleh, 2011). Several researchers have also compared DEA and SFA (Margari et al., 2007; Pevcin, 2014), while others have combined DEA and FDH analyses in their studies (De Borger and Kerstens, 1996; Geys and Moesen, 2009). Across these works, a

consistent conclusion emerges pointing to substantial potential for improving public sector efficiency.

These analyses span a wide range of countries and periods. While many studies focus on Europe (Handler et al., 2007; Mihaiu et al., 2010; Halaskova et al., 2018) and OECD countries (Afonso et al., 2005; Curristine et al., 2007), others examine regions such as Latin America (Afonso et al., 2013), West Asia (Ouertani et al., 2018), and countries across the globe (Gupta and Verhoeven, 2001; Wandeda et al., 2021).

To further understand cross-country efficiency gaps, a related strand of the literature has explored determinants of government spending efficiency, including factors such as population size, educational composition, income levels, and the quality of institutions and governance (see, for example, Afonso et al., 2005; Hauner and Kyobe, 2010; Fonchamnyo and Sama, 2016; Adegboye and Akinyele, 2022). Afonso and St. Aubyn (2006) find that income level and parental education influence the efficiency of education spending in OECD countries. Similarly, Afonso et al. (2005) highlight the role of income and education in driving efficiency, while Hauner (2008) shows that higher government efficiency is associated with higher per capita income.

Another stream of research focuses on the relationship between government size and public sector efficiency. Angelopoulos et al. (2008) examine whether efficiency moderates the relationship between fiscal size and economic growth. They suggest that greater efficiency can offset the potential negative impact of a large public sector. De Witte and Moesen (2010) identify a U-shaped relationship between government size and economic performance, proposing that both excessively small and overly large governments can reduce efficiency, and they argue for an "optimal" relative size of the public sector.

Further studies investigate the relationship between taxation and efficiency. Afonso et al. (2021) conduct an international comparison of tax systems and public spending efficiency. Using DEA techniques to construct efficiency scores, they find that higher tax levels do not necessarily lead to inefficiency, depending on how public resources are managed. Adam et al. (2014) identify an inverted U-shaped relationship between government efficiency in service delivery and fiscal decentralization, suggesting that moderate decentralization may enhance efficiency, while excessive or insufficient decentralization could have the opposite effect.

3. Methodology

3.1. SDGs indices

We consider the time series of each target of the SDGs, 169 in total, from Eurostat in the period 1995-2023[2]. We consider 27 countries of the European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovak Republic, Spain, and Sweden.

Firstly, we follow Onrubia et al. (2022), and we use the following transformations to normalize the targets of the SDGs and assign them a value between 0 and 1. The next expression was used for the direct variables, i.e. those variables in which a higher value indicates a higher probability of a country to achieve the goal:

$$h = \frac{H_i - H_{min}}{H_{max} - H_{min}} \tag{1}$$

where H is the real value achieved by country i in a given year, H_{min} is the minimum value achieved in that target among the countries in that year, and H_{max} is the maximum value reached among the countries in that given year.

For the inversely defined targets, i.e. those variables in which a higher value indicates a lower probability of a country achieving the goal, the following normalization methodology is used:

$$h = \frac{H_{max} - H_i}{H_{max} - H_{min}} \tag{2}$$

where H is the real value achieved by country i in a given year, H_{min} is the minimum value achieved in that target among the countries in that year, and H_{max} is the maximum value reached among the countries in that given year. Thus, ensuring that h will take the value of 1 when country i succeeds in the performance of the target, and 0 when the opposite occurs.

[2] The database is available upon request from the authors.

Once all the targets within each goal have been normalized between 0 and 1, they are added to obtain the partial synthetic indices relative to each goal (17 in our case) and divided by the number of targets used in each block:

$$y_i = \frac{\sum_{i=1}^{n} h_i}{n} \tag{3}$$

where h_i represents the normalized values of the targets and n is the number of targets in each SDG.

Finally, Tremblay et al. (2020) developed a classification of the SDGs according to the five pillars set out in the 2030 Agenda. To do so, they distributed a survey to practitioners in which they inquired about the degree of association of the 169 targets to each of the five pillars. To rank the targets, they designed a scoring system based on the level of exclusiveness or inclusiveness of a pillar. They analysed the overall percentage frequency of each pillar in each target. Finally, the authors assess the correlation between all possible pairs of targets. To do so, they apply Pearson's correlation coefficient using target scores as variables. Thus, following the classification of Tremblay et al. (2020), each index is multiplied by the corresponding weight, then summed to obtain the partial synthetic indices for each pillar, and finally divided by the total SDGs:

$$g_i = \frac{\sum_{i=I}^{n} y_i \cdot w_i}{n\ (SDGs)} \tag{4}$$

where g_i represents the partial synthetic index for each pillar, y_i is the synthetic index relative to each goal, w_i is the corresponding weight obtained from the classification of Tremblay et al. (2020) and n is the total number of goals (17).

The consideration of this classification allows us to understand the relationship between the different economic and social agents together, so as not to isolate them with the classification of the SDGs. At the same time, it is worth mentioning that the SDG classification is the result of previous aggregations, which could have the same weaknesses as the pillar classification.

However, the development of the synthetic indices and the ranking of Tremblay et al. (2020) have some limitations. First, the clustering into pillars and the standardization process may be affected by heterogeneity across countries. A wide diversity in terms of development, priorities and policies can make the results not fully representative and comparable. Second, one of the main drawbacks of the classification proposed by Tremblay et al. (2020) is the exclusion of targets related to the means of implementation, which could affect the representativeness of the classification. Third, although the methodology of Tremblay et al. (2020) assigns weights to the SDGs following the institutional structure of the 2030 Agenda, which helps to reduce methodological biases, it also implies ignoring that governments may prioritize certain goals over others (Cristóbal et al., 2021; De la Cruz and Onrubia, 2024). Finally, the introduction of an additional SDG aggregation step could dilute the original dynamic of the data, leaving out sensible information on the specific relationship between the SDGs.

3.2. Data Envelopment Analysis

In our analysis, public sector efficiency scores are the variables of interest, calculated through Data Envelopment Analysis (DEA). This methodology compares each observation to an optimal outcome. It is an optimal approach for several reasons. First, it does not impose an underlying production function. Second, it allows for deviations from the efficient frontier and examines a country's efficiency relative to its peers. Formally, for each country i ($i = 1, \dots, 27$), we consider the following function:

$$y_i = \gamma + f(X_i), i = 1, \dots, 27 \quad (5)$$

where y is the composite measure of output, i.e., pillars of the SDGs, and X is the composite measure of inputs, i.e., public spending. We employ both output-oriented and input-oriented approaches to measure the efficiency of countries. The output-oriented approach evaluates the proportional increase in outputs while keeping inputs constant and assuming variable returns to scale, to account for the fact that countries might not be operating at an optimal scale. In the input-oriented approach, we measure the proportional reduction in inputs required to achieve the same levels of output.

Formally and for instance for the input-oriented approach, efficiency scores are computed solving the following linear programming problem:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ s.t. \quad &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &I1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \tag{6}$$

where y_i is a vector of outputs, x_i is a vector of inputs, θ is the efficiency scores, λ is a vector of constants, $I1'$ is a vector of ones, X is the input matrix and Y is the output matrix.

The efficiency scores, θ, range from 0 to 1, such that countries performing in the frontier score 1. More specifically, if $\theta < 1$, the country is inside the production frontier (i.e., it is inefficient), and if $\theta = 1$, the country is at the frontier (i.e., it is efficient).

The DEA model is a non-parametric technique used to evaluate the efficiency of Decision-Making Units (DMUs) by comparing their inputs and outputs. In our analysis, we applied this model using four inputs based on Musgravian function of the spending government: *redistribution*, *allocation*, *general public services* and *private activities*, and five outputs represented by the pillars of the SDGs: *people*, *planet*, *peace*, *prosperity* and *partnership*.

The purpose of this DEA model is to analyze the relative efficiency with which public expenditure is used to improve the achievement of the pillars of the SDGs. The main objective is to determine whether the economies considered in our analysis are efficient by comparing their public expenditure with their results in the pillars of the SDGs. The public sector will be considered efficient if it achieves greater growth in these pillars without significantly increasing its public expenditure, in other words, if it manages to "do more with less."

4. Empirical Analysis

4.1. Data

Table 1 presents the level of public expenditure as a percentage of GDP for each country and for the years 2003, 2013, and 2023. The data are structured according to the Musgravian classification of public expenditure, which distinguishes four main components:

redistribution, *allocation*, *public services*, and *private activities*. The *redistribution* function encompasses spending on health, education, and social protection. *Allocation* includes expenditure on defense, law and order, security, and environmental protection. *Public services* refer to the combined spending on general public services, housing, and community amenities. *Private activities* comprise spending related to economic affairs, as well as culture, leisure, and religion.

Between 2003 and 2013, several countries reduced their redistribution expenditure, a trend partly attributable to the effects of the 2008 financial crisis. This was the case for Austria, Croatia, Germany, Latvia, Poland, and Sweden, all of which subsequently returned to their pre-crisis levels of redistribution spending by 2023. In contrast, the remaining countries increased their expenditure in redistribution throughout the entire period considered. Ireland, in particular, experienced an increase in redistribution spending from 2003 to 2013, followed by a sharp decrease of 8.4 p.p. of GDP between 2013 and 2023. Hungary also recorded a notable decline of 4.14 p.p. in this category over the same latter period.

In terms of allocation expenditure, most countries maintained stable levels from 2003 to 2023. The only exception is the Slovak Republic, which reduced its allocation spending by 2.113 p.p. of GDP between 2003 and 2013.

With regard to public services, the general trend across countries was a reduction in spending between 2003 and 2023. However, Cyprus and the Czech Republic deviated from this pattern in the first decade, increasing their public services expenditure by 1.388 and 1.134 p.p. of GDP, respectively, from 2003 to 2013. Both countries then decreased this type of spending in the following period, from 2013 to 2023.

As for private activities, most countries kept their spending levels relatively stable over time. Notable exceptions include the Czech Republic and the Slovak Republic, which reduced their spending on private activities by 2.973 and 3.313 p.p., respectively, between 2003 and 2013. Both countries later recovered these levels in the subsequent period, from 2013 to 2023. Ireland, however, experienced a decline of 4.09 p.p. in private activities expenditure between 2013 and 2023.

In summary, Denmark, Finland and Ireland reduced its spending across all four categories – *redistribution*, *allocation*, *public services*, and *private activities* – between 2003 and 2023. Estonia, on the other hand, increased its spending in all these categories over the same period.

Meanwhile, France, Greece, Italy, and Latvia registered increases in all categories except for public services, where spending either remained stable or declined.

Table 1. Evolution of public expenditure by Musgravian classification 2003-2023

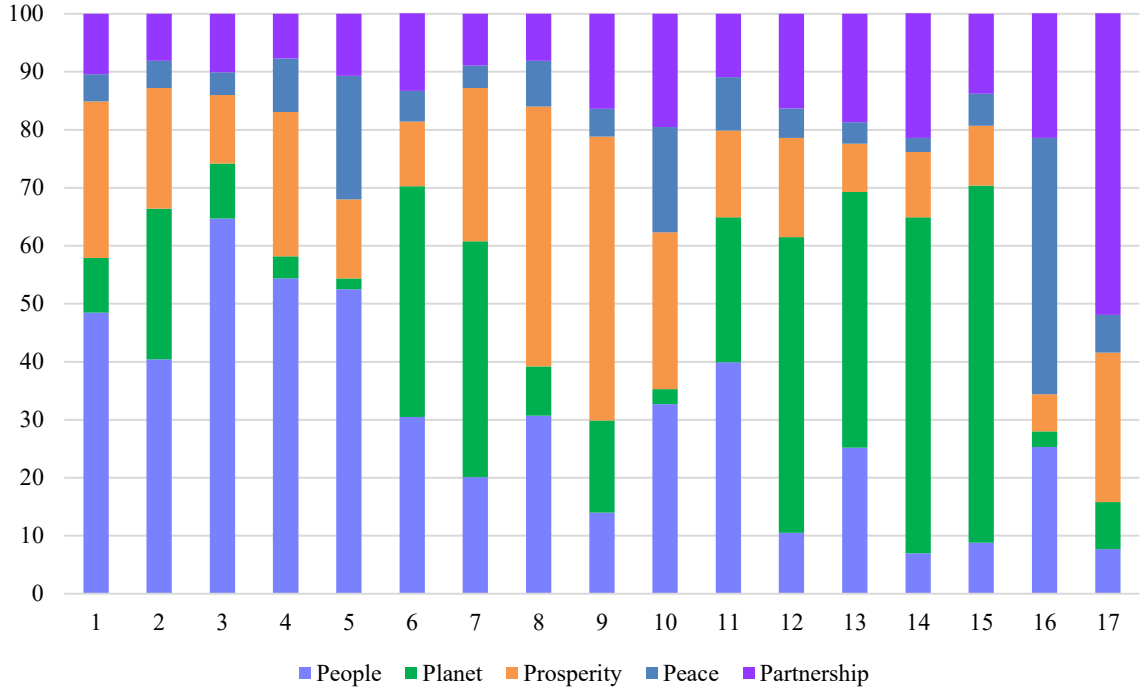
	Redistribution			*Allocation*			*Public services*			*Private activities*		
	2003	**2013**	**2023**	**2003**	**2013**	**2023**	**2003**	**2013**	**2023**	**2003**	**2013**	**2023**
Austria	33.522	33.270	34.940	2.967	2.560	2.400	9.433	7.980	6.420	6.922	8.250	8.410
Belgium	29.311	31.490	34.130	3.611	3.870	3.880	12.222	9.280	7.740	5.767	7.840	8.110
Bulgaria	18.056	19.840	21.870	5.067	4.850	4.670	9.889	6.020	5.040	4.411	5.690	7.400
Croatia	30.333	25.740	26.630	5.944	4.510	4.180	6.322	6.290	7.320	11.178	10.800	9.030
Cyprus	17.411	22.450	23.810	4.522	4.760	4.010	9.722	11.110	8.940	4.956	5.660	5.840
Czech Republic	23.489	24.420	25.360	4.578	3.990	3.650	4.956	6.090	5.330	10.933	7.960	7.750
Denmark	36.856	37.930	36.570	3.033	2.880	2.570	9.856	7.700	6.320	5.344	5.090	5.250
Estonia	21.811	22.460	24.350	4.589	4.390	4.640	4.056	3.850	4.270	6.967	7.000	7.020
Finland	33.978	34.720	38.550	3.167	3.070	2.690	8.456	7.870	7.250	6.867	5.910	6.140
France	33.978	36.050	38.230	4.311	4.320	4.410	9.033	8.370	7.340	6.111	6.280	7.500
Germany	31.122	30.000	31.300	3.433	3.060	3.130	7.856	7.160	6.310	6.767	5.670	6.070
Greece	22.944	28.250	29.860	4.200	5.330	5.950	13.622	11.840	8.780	6.278	7.120	7.360
Hungary	26.156	27.550	23.410	3.833	3.710	3.850	12.156	10.460	9.410	7.833	7.950	11.640
Ireland	21.178	25.870	17.470	2.856	2.830	1.590	6.133	5.800	3.780	4.278	7.170	3.080
Italy	27.022	29.960	32.520	3.889	4.030	4.020	12.656	9.870	9.220	4.722	4.840	5.910
Latvia	22.300	21.510	23.280	3.700	4.070	4.870	5.444	6.000	5.350	5.844	8.990	8.240
Lithuania	22.022	23.540	23.210	3.433	3.850	3.700	6.722	4.980	4.150	6.389	5.250	4.900
Luxembourg	25.600	26.580	28.340	2.189	2.080	2.460	6.167	5.820	5.500	6.956	6.660	6.630
Malta	23.144	24.150	20.610	3.422	3.610	3.010	7.756	7.680	5.880	7.167	6.020	7.600
Netherlands	26.233	28.520	29.140	4.644	4.660	4.420	8.689	6.140	4.620	6.767	6.670	6.130
Poland	27.644	26.490	26.550	4.622	4.560	4.400	8.678	6.580	5.120	4.778	6.390	6.990
Portugal	24.922	29.880	29.170	3.822	3.890	3.300	8.100	8.400	7.670	6.433	5.750	5.750
Romania	17.144	18.640	20.180	3.744	4.250	4.540	7.967	5.930	5.830	6.778	7.900	6.640
Slovak Republic	23.756	24.070	25.560	6.333	4.220	4.440	8.222	5.660	5.780	9.133	5.820	6.980
Slovenia	30.567	31.200	30.460	3.578	3.910	3.390	7.144	6.460	6.250	6.456	7.180	7.400
Spain	22.478	25.330	28.740	3.822	3.960	3.730	7.900	6.510	6.370	6.211	7.160	5.960
Sweden	37.133	35.400	34.680	3.844	3.260	3.200	9.411	6.870	6.090	6.133	5.880	6.460
Average	26.300	27.604	28.108	3.969	3.870	3.744	8.465	7.286	6.373	6.607	6.774	6.896
Min	17.144	18.640	17.470	2.189	2.080	1.590	4.056	3.850	3.780	4.278	4.840	3.080
Max	37.133	37.930	38.550	6.333	5.330	5.950	13.622	11.840	9.410	11.178	10.800	11.640

Notes: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Secondly, we obtain the partial additive indices for each pillar, based on the weights determined by Tremblay et al. (2020). In Figure 1 we include weights in each goal of the 2030 Agenda. The *people* pillar refers to human well-being and the eradication of poverty and hunger, and is primarily associated with Goals 1, 2, 3, 4, 5, and 11. The *planet* pillar focuses on sustainable consumption and production, the responsible management of natural resources, and urgent action to combat climate change. Indeed, it is linked to Goals 6, 7, 12, 13, 14, and 15. The *prosperity* pillar addresses economic, social, and technological progress in harmony with nature, and corresponds to Goals 1, 7, 8, 9, and 10. The *peace* pillar refers to peaceful, just, and inclusive societies, and is connected to Goals 5, 10, and 16. Lastly, the *partnership* pillar reflects the importance of collaboration for the implementation of the 2030 Agenda, and is associated with Goals 10, 14, 16, and 17 (see Figure 1) (United Nations, 2015a; United

Nations, 2015b; Lee et al., 2016; United Nations, 2020). All indices have been normalized on a scale from 0 to 100%, where 0 indicates no achievement of the pillar, and 100% represents full achievement.

Figure 1. Relative distribution of the 5 pillars among the 17 SDGs



Source: Tremblay et al. (2020).

Table 2 presents the evolution, expressed in percentages, of the five pillars used to classify the 17 SDGs by country for the period 2003-2023. These pillars —*people*, *planet*, *prosperity*, *peace*, and *partnership*— reflect different dimensions of sustainable development.

In the case of the people pillar, all countries show improvement between 2003 and 2023. However, the average increase across countries is relatively modest, around 15% of total achievement. In 2003, Malta had the lowest performance in this pillar, scoring 1.069%, while Finland recorded the highest at 3.247%. In 2013 and 2023, Romania showed the lowest scores (6.720% and 8.786%, respectively), whereas Sweden had the highest (13.828% and 15.736%).

For the planet pillar, again, all countries improved their scores between 2003 and 2023, although the average increase was around 9%. In 2003, Malta ranked lowest at 1.126%, while Ireland had the highest value at 2.026%. In both 2013 and 2023, Malta remained the lowest-

performing country (4.633% and 5.774%), while Finland achieved the highest scores (7.913% and 9.030%).

In terms of the prosperity pillar, all countries recorded progress from 2003 to 2023, with an average increase of around 10%. In 2003, Malta once again had the lowest score (0.673%), while Finland achieved the highest (2.076%). By 2013 and 2023, Romania held the lowest scores (4.375% and 5.590%), and Sweden the highest (8.414% and 9.939%).

Regarding the partnership pillar, all countries experienced improvements over the two decades, with an average increase of approximately 6%. Romania had the lowest score in 2003 (0.637%), while Denmark led with 1.445%. Romania continued to register the lowest performance in 2013 and 2023 (3.089% and 3.712%, respectively), whereas Sweden recorded the highest scores (5.567% and 6.148%).

For the peace pillar, although all countries improved from 2003 to 2023, this dimension shows the lowest overall progress, with an average achievement of only 4% by 2023. Malta scored the lowest in 2003 with 0.328%, and Denmark the highest with 0.973%. In both 2013 and 2023, Romania ranked last (2.008% and 2.287%), while Sweden scored highest (3.849% and 4.008%).

In summary, the countries with the lowest performance across the five pillars include Malta, which had the lowest scores in 2003 for the people, planet, prosperity, and peace pillars, and continued to rank lowest for the planet pillar in both 2013 and 2023. Romania also stands out for low performance, recording the lowest values in 2003 for the partnership pillar, and in 2013 and 2023 for the people, prosperity, partnership, and peace pillars. The countries with the highest levels of SDG achievement in 2003 were Finland for the people and prosperity pillars, Ireland for the planet pillar, and Denmark for both the partnership and peace pillars. In 2013 and 2023, Sweden emerged as the top-performing country in four of the five pillars: people, prosperity, partnership, and peace, while Finland maintained the highest score in the planet pillar. Overall, peace is the least achieved pillar, with an average accomplishment of just 4% across all countries in 2023, while people is the most advanced pillar, reaching an average of 15% in the same year.

Table 2. Evolution of the pillars of the SDGs 2003-2023

	People			*Planet*			*Prosperity*			*Partnership*			*Peace*		
	2003	**2013**	**2023**	**2003**	**2013**	**2023**	**2003**	**2013**	**2023**	**2003**	**2013**	**2023**	**2003**	**2013**	**2023**
Austria	2.608	11.582	13.769	1.973	7.410	7.994	1.541	7.389	9.023	1.227	4.769	5.400	0.772	3.254	3.599
Belgium	2.739	11.420	13.612	1.811	6.291	7.716	1.640	6.808	8.508	1.198	4.415	5.244	0.714	3.130	3.446
Bulgaria	1.964	7.985	10.156	1.574	4.824	6.332	1.171	4.737	6.081	0.982	3.236	4.007	0.593	2.194	2.457
Croatia	1.428	7.458	12.094	1.538	5.177	7.072	0.896	4.562	7.086	0.837	3.196	4.569	0.404	2.248	3.208
Cyprus	2.044	9.891	12.570	1.294	5.174	6.267	1.171	5.758	7.369	0.803	3.666	4.460	0.530	2.885	3.187
Czech Republic	1.923	10.444	13.238	1.610	6.144	7.267	1.308	6.694	8.790	1.033	4.187	5.146	0.601	2.917	3.417
Denmark	3.183	12.635	14.635	1.976	7.173	8.723	2.000	7.851	9.429	1.445	5.039	5.868	0.973	3.532	3.838
Estonia	2.416	10.241	12.380	1.836	6.459	7.799	1.466	6.598	7.999	1.126	4.081	4.891	0.593	2.627	3.166
Finland	3.247	13.144	14.659	1.982	7.913	9.030	2.076	8.326	9.502	1.404	5.223	5.822	0.939	3.610	3.808
France	2.640	11.379	13.376	1.724	6.318	7.365	1.540	6.964	8.325	1.199	4.457	5.098	0.761	3.148	3.460
Germany	2.611	10.552	12.837	1.851	6.525	7.757	1.616	6.796	8.647	1.230	4.339	5.237	0.788	3.038	3.335
Greece	2.175	8.822	10.217	1.493	5.392	6.378	1.282	5.095	5.985	1.006	3.472	4.000	0.730	2.582	2.695
Hungary	2.115	9.005	11.328	1.603	5.275	6.222	1.364	5.556	7.304	1.057	3.627	4.376	0.645	2.550	2.851
Ireland	2.717	12.191	14.267	2.026	7.060	8.021	1.631	6.925	8.493	1.284	4.708	5.355	0.833	3.379	3.712
Italy	1.997	9.200	11.227	1.847	6.426	7.400	1.213	5.643	6.810	1.013	3.801	4.504	0.599	2.524	2.872
Latvia	1.866	8.947	11.954	1.885	6.130	7.593	1.137	5.726	7.403	1.004	3.673	4.646	0.419	2.264	2.959
Lithuania	2.201	9.734	12.875	1.640	5.693	7.235	1.266	5.827	7.664	1.029	3.910	4.942	0.585	2.720	3.371
Luxembourg	2.365	11.313	13.044	1.625	6.014	6.665	1.529	7.264	8.438	1.224	4.697	5.221	0.757	3.289	3.499
Malta	1.069	7.921	10.945	1.126	4.633	5.774	0.673	4.648	6.727	0.637	3.118	4.171	0.328	2.191	2.778
Netherlands	2.666	11.468	14.244	1.588	5.963	7.317	1.643	7.164	9.134	1.236	4.446	5.322	0.823	3.202	3.645
Poland	1.979	9.645	12.497	1.513	5.539	6.503	1.149	5.575	7.593	0.984	3.783	4.624	0.607	2.916	3.355
Portugal	1.770	8.859	11.750	1.508	5.759	6.764	1.284	5.682	7.276	0.990	3.844	4.604	0.552	2.588	3.134
Romania	1.962	6.720	8.786	1.654	4.728	5.926	1.079	4.375	5.590	0.991	3.089	3.712	0.543	2.008	2.287
Slovak Republic	1.874	9.555	12.307	1.688	5.916	6.833	1.168	5.707	7.444	1.011	3.864	4.658	0.557	2.743	3.208
Slovenia	2.095	10.907	13.766	1.532	6.159	7.576	1.328	6.706	8.601	1.030	4.215	5.156	0.672	3.186	3.655
Spain	2.529	10.632	11.960	1.835	6.493	6.951	1.484	6.257	6.958	1.177	4.259	4.560	0.771	2.966	3.069
Sweden	2.984	13.828	15.736	1.857	7.908	8.775	1.685	8.414	9.939	1.366	5.567	6.148	0.893	3.849	4.008
Average	2.265	10.203	12.601	1.689	6.093	7.232	1.383	6.261	7.856	1.093	4.099	4.879	0.666	2.872	3.260
Min	1.069	6.720	8.786	1.126	4.633	5.774	0.673	4.375	5.590	0.637	3.089	3.712	0.328	2.008	2.287
Max	3.247	13.828	15.736	2.026	7.913	9.030	2.076	8.414	9.939	1.445	5.567	6.148	0.973	3.849	4.008

Notes: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

4.2. Results

First, from data of the 169 targets of the SDGs available in Eurostat for 27 countries of the European Union between 1995 and 2023, we compute the indices of the 5 pillars of the SDGs.

In a second step, we obtain the government spending in COFOG from Eurostat for 27 countries between 1995 and 2023. We consider the Musgravian functions to classify the government spending by COFOG.

Finally, we compute DEA with four inputs (Musgravian functions of the government spending) and five outputs (pillars of the SDGs) by periods: 1995-2003; 2004-2013; 2014-2023, and we obtain the efficiency scores of this model. Tables 3 and 4 show the input and output oriented, variable returns to scale, technical efficiency scores for each country for each abovementioned. Eight among 27 countries analysed are efficient for the period 1995-2003. Thirteen among the 27 countries analysed are efficient for the period 2004-2013. Five among 27 countries analysed are efficient for the period 2014-2023.

Table 3 shows the input-oriented efficiency scores for the period 2003, 2013 and 2023, and for 27 countries. For instance, for 2003, we obtain 8 countries on the frontier, that is, efficient: Bulgaria, Cyprus, Denmark, Estonia, Finland, Ireland, Luxembourg, and Romania. The less efficient country is France (0.700). The efficiency scores range from 0.700 to 1 with an average score of 0.891. This implies that on average countries could be able to keep the same level output while decreasing inputs by around 10.9%. Alternatively, in Table 4, which reports the output-oriented efficiency scores, we obtain the same countries in the efficiency frontier, while the less efficient country is Malta (0.556).

Secondly, from the input-oriented model in the period between 2004 and 2013 we obtain 13 countries on the frontier: Austria, Bulgaria, Cyprus, Denmark, Estonia, Finland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Romania and Sweden. The less efficient country is Greece (0.787). The efficiency scores range from 0.787 to one. From the output-oriented perspective, we obtain the same efficient countries, with the less efficient country Croatia (0.736). The efficiency scores go from 0.736 to one.

Lastly, from the input-oriented results in the period between 2014 and 2023 we obtain 5 efficient countries: Denmark, Finland, Ireland, and Netherlands. The less efficient country is France (0.515). From the output-oriented model, we obtain Romania as the less efficient country (0.727), with the same efficient countries from the input-oriented results.

Denmark, Finland and Ireland, are the only countries that remain efficient in all periods considered in the analysis, that is, they are always on the frontier. Between 1995 and 2013, the following countries are also efficient: Bulgaria, Cyprus, Estonia, Luxembourg, and Romania. Sweden shows efficiency from the period 2004-2023. Austria is efficient in the period 2004-2013, while Netherlands is only efficient between 2014 and 2023.

The previous results also show the capacity to improve output is rather stable over time. On average, the European countries could theoretically increase their output by 10.9% and 10.8% (input and output oriented, respectively) between 1995 and 2003; by 5% and 7% (input and output oriented, respectively) between 2004 and 2013; by 23.5% and 11.7% (input and output oriented, respectively) between 2014 and 2023.

Table 3. Input-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)

	2003	Rank	Peers	2013	Rank	Peers	2023	Rank	Peers
Austria	0.933	10	IRL LUX	1.000	1	AUT	0.894	7	IRL DNK
Belgium	0.785	24	LUX IRL DNK	0.824	26	LTU IRL SWE CYP LUX	0.517	26	SWE IRL
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.799	12	IRL
Croatia	0.713	26	EST ROU IRL	0.840	25	LUX EST ROU	0.656	19	IRL
Cyprus	1.000	1	CYP	1.000	1	CYP	0.734	16	IRL
Czech Republic	0.920	12	EST ROU IRL	0.972	17	IRL EST CYP	0.828	11	IRL SWE
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	0.885	8	IRL
Finland	1.000	1	FIN	1.000	1	FIN	1.000	1	FIN
France	0.700	27	IRL	0.845	24	SWE LTU DNK	0.515	27	IRL
Germany	0.788	23	FIN LUX IRL	0.996	14	FIN DNK LTU LUX	0.635	20	IRL SWE NLD
Greece	0.860	17	IRL ROU	0.787	27	CYP IRL LTU BGR LUX	0.585	24	IRL
Hungary	0.784	25	IRL ROU	0.848	23	LUX ROU BGR	0.746	14	IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.906	13	IRL	1.000	1	ITA	0.537	25	IRL
Latvia	0.966	9	IRL EST LUX	1.000	1	LVA	0.750	13	IRL
Lithuania	0.931	11	IRL EST ROU	1.000	1	LTU	0.911	6	IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.687	17	IRL
Malta	0.883	16	IRL ROU	0.975	16	LTU BGR LUX	0.848	10	IRL
Netherlands	0.821	19	IRL FIN	0.955	18	SWE IRL CYP LUX LTU	1.000	1	NLD
Poland	0.895	15	IRL	0.908	21	IRL SWE CYP LTU	0.738	15	IRL
Portugal	0.810	21	IRL ROU EST	0.913	20	LUX DNK LTU	0.599	23	IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.866	9	IRL
Slovak Republic	0.794	22	EST ROU	0.976	15	FIN EST LTU IRL	0.683	18	IRL
Slovenia	0.820	20	EST LUX IRL	0.863	22	EST SWE IRL LUX LTU	0.629	21	IRL NLD SWE
Spain	0.904	14	ROU IRL	0.945	19	IRL EST LTU CYP BGR	0.608	22	IRL
Sweden	0.845	18	FIN IRL DNK	1.000	1	SWE	1.000	1	SWE
Average	0.891			0.950			0.765		
Countries on the frontier	8			13			5		
Max	1.000			1.000			1.000		
Min	0.700			0.787			0.515		

Notes: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Finally, Figures 2 and 3 display the DEA VRS efficiency scores – both input and output-oriented – for the 27 economies considered, comparing the first period (1995–2003) with the most recent one (2014–2023).

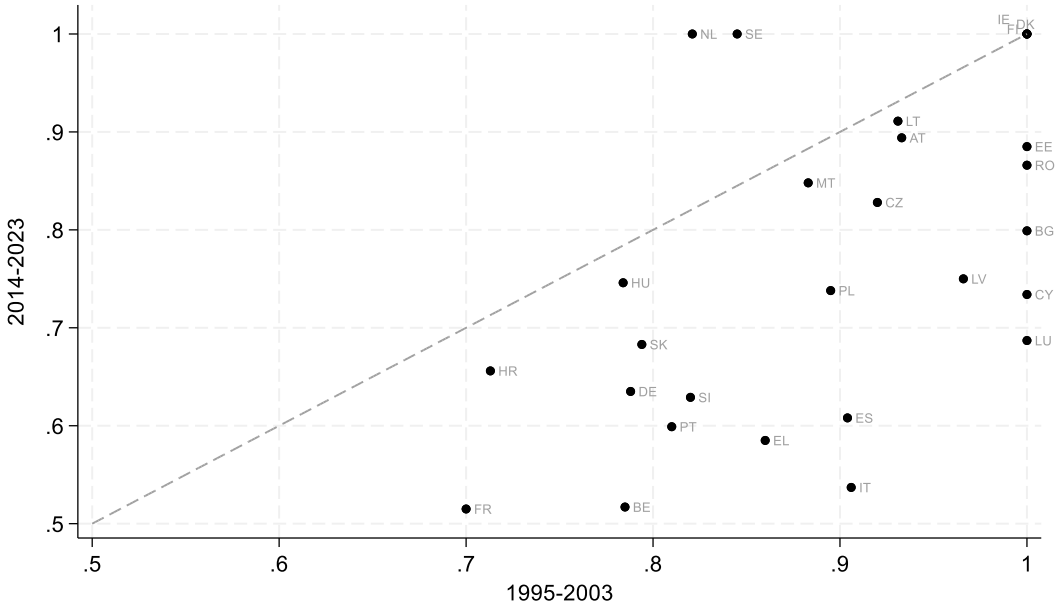
Once again, we find that Denmark, Finland, and Ireland lie on the efficiency frontier in both the initial and final periods. The Netherlands and Sweden reach efficiency only in the final period. In contrast, Bulgaria, Cyprus, Estonia, Luxembourg, and Romania were efficient solely during the 1995–2003 period.

Table 4. Output-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)

	2003	Rank	Peers	2013	Rank	Peers	2023	Rank	Peers
Austria	0.974	9	IRL	1.000	1	AUT	0.974	6	IRL DNK
Belgium	0.905	16	FIN DNK IRL	0.871	21	IRL LUX SWE	0.880	14	FIN SWE IRL
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.769	24	FIN IRL
Croatia	0.759	24	IRL	0.736	27	EST IRL	0.838	19	FIN IRL SWE
Cyprus	1.000	1	CYP	1.000	1	CYP	0.849	17	IRL SWE
Czech Republic	0.865	17	EST IRL	0.975	15	IRL EST LUX	0.960	7	IRL SWE
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	0.953	8	SWE IRL
Finland	1.000	1	FIN	1.000	1	FIN	1.000	1	FIN
France	0.865	17	FIN DNK IRL	0.828	22	SWE	0.863	16	SWE
Germany	0.921	13	IRL DNK FIN	0.990	14	FIN DNK LTU LUX	0.899	13	IRL SWE FIN
Greece	0.859	19	IRL DNK	0.741	26	IRL FIN SWE	0.740	26	IRL FIN
Hungary	0.797	22	DNK IRL	0.764	24	EST IRL SWE LUX	0.812	22	IRL SWE
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.911	15	IRL	1.000	1	ITA	0.847	18	FIN IRL
Latvia	0.960	10	EST IRL	1.000	1	LVA	0.915	10	FIN IRL
Lithuania	0.809	21	IRL FIN	1.000	1	LTU	0.902	12	SWE IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.909	11	IRL DNK SWE
Malta	0.556	27	IRL	0.750	25	IRL EST LTU CYP	0.768	25	IRL SWE
Netherlands	0.937	12	IRL FIN DNK	0.957	17	IRL SWE LUX	1.000	1	NLD
Poland	0.750	25	IRL DNK	0.894	19	SWE LTU CYP IRL	0.867	15	IRL SWE
Portugal	0.749	26	IRL DNK	0.821	23	IRL FIN EST LTU	0.801	23	IRL SWE
Romania	1.000	1	ROU	1.000	1	ROU	0.727	27	IRL FIN
Slovak Republic	0.833	20	IRL	0.973	16	FIN EST IRL LTU	0.833	20	IRL SWE
Slovenia	0.771	23	IRL FIN	0.875	20	IRL SWE	0.929	9	IRL SWE
Spain	0.914	14	DNK FIN IRL	0.932	18	IRL EST	0.813	21	FIN IRL SWE
Sweden	0.954	11	FIN DNK	1.000	1	SWE	1.000	1	SWE
Average	0.892			0.930			0.883		
Countries on the frontier	8			13			5		
Max	1.000			1.000			1.000		
Min	0.556			0.736			0.727		

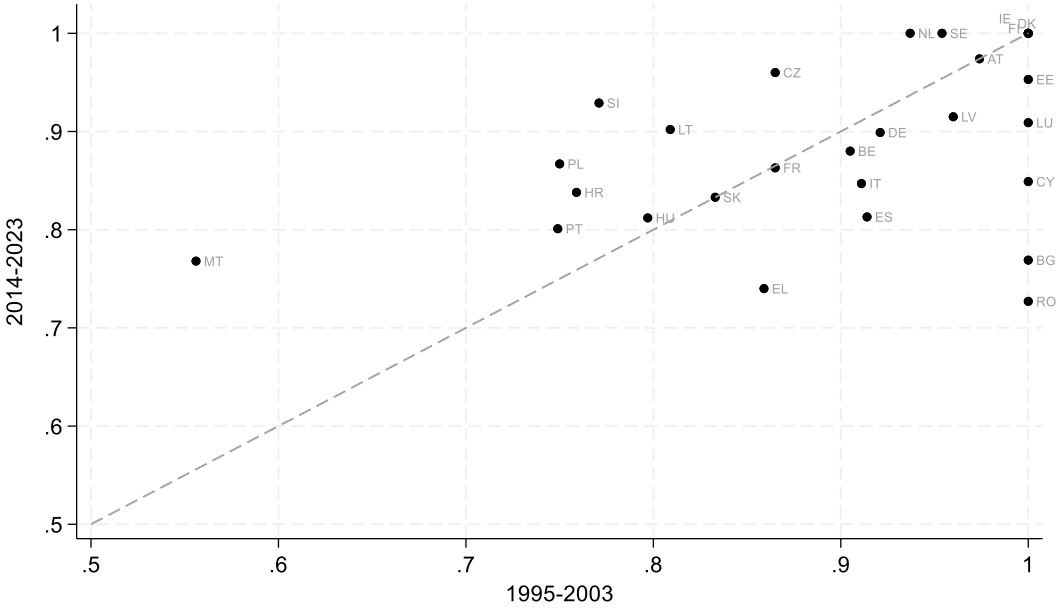
Notes: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Figure 2. Relationship between input-oriented DEA VRS efficiency scores in 2003 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)



Notes: We consider the following periods: 1995-2003 and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Figure 3. Relationship between output-oriented DEA VRS efficiency scores in 2003 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)



Notes: We consider the following periods: 1995-2003 and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

4.3. Robustness test

Finally, to assess the robustness of the results presented in the previous section, we replicate the DEA model using the Musgravian classification of public expenditure but apply two alternative methods to construct the SDG pillar indices.

As an alternative to the first methodology (Methodology 1), which estimates public spending efficiency in achieving the SDGs by constructing normalized weighted indices ranging from 0 to 1 using the weights proposed by Tremblay et al. (2020), we apply Methodology 2. This second approach computes the SDG indices through Principal Component Analysis (PCA), conducted separately for three distinct time periods: 1995-2003, 2004-2013, and 2014-2023. In the first period (1995-2003), two components with eigenvalues greater than 1 are extracted, in accordance with the Kaiser criteria. In the second period (2004-2013), four such components are identified, while in the third period (2014-2023), five components meet this threshold (see Appendix A.1., Tables A1 and A2).

Methodology 3, in turn, relies on a textual analysis of the metadata sections accompanying the SDG targets published by Eurostat (see Appendix A.2., Tables A4 and A5). This approach involves constructing a dictionary of key terms associated with each target, based on their textual descriptions. A word frequency analysis is then performed using sentiment analysis techniques, excluding non-informative terms. The goal is to establish a weighted ranking of the SDGs according to their association with the five pillars: people, planet, peace, partnership, and prosperity. The resulting word frequencies are used to derive weights for each SDG, reflecting the relative prominence of pillar-related terms in each target's description.

The results, for the frequency of efficient countries, obtained using all three methodologies of the efficiency scores, both input and output-oriented, revealing consistent patterns across them (see Appendix A.3., Tables A6 and A7). Denmark and Ireland are classified as efficient in every period and across all three methodologies. Finland follows closely, being considered efficient in 8 out of the 9 periods analyzed. Bulgaria, Estonia, Luxembourg, Romania, and Sweden also demonstrate high efficiency, each being classified as efficient in 7 of the 9 periods, though missing in some years depending on the methodology applied. These results remain consistent when analyzed from both input and output perspectives.

Finally, as an alternative to the index calculation method based on the min-max criterion, an additional robustness test was conducted for the three methodologies previously described. In this new evaluation, the approach to estimating the SDG targets was modified.

For direct variables, the proportion between the target value of a given country in a specific year and the corresponding average of that target across the 27 countries considered in the same year was calculated. In the case of inverse variables, the opposite approach was applied: the average target value was used as an inverse reference.

Given that the correlation between both methodologies across the different targets is high (above 0.9), it is concluded that there are no significant differences between using one calculation strategy or the other. The results obtained through this alternative approach are consistent with those derived from the min-max method (see Appendix B for more information), which reinforces the robustness and reliability of the conclusions reached.

5. Conclusions

This study has assessed the efficiency of public expenditure in the EU-27 countries in relation to the achievement of the SDGs, using a DEA framework. Anchored in the five pillars of the 2030 Agenda – *people*, *planet*, *prosperity*, *peace*, and *partnership* – our findings provide a comprehensive overview of how efficiently public resources are being allocated to advance sustainable development.

The DEA models reveal important differences across countries. Input efficiency scores range from 0.77 to 0.95, indicating that public inputs could potentially increase by 5% to 23.5% without altering output levels. On the other hand, output efficiency scores between 0.88 and 0.93 suggest that countries could improve SDG outcomes by 7% to 11.7% while maintaining current expenditure levels.

Notably, Ireland, Denmark, and Finland exhibit the highest levels of efficiency throughout the period 1995-2023, with consistent reductions in public spending – particularly in the categories of allocation, public services, and private activities. Ireland also reduced its public spending in redistribution. Sweden also reduced spending in all areas except private activities and ranks among the top performers in SDG achievement. These cases illustrate that selective and strategic reductions in public expenditure do not necessarily hinder progress and may, in fact, align with greater efficiency.

In terms of performance across SDG pillars, Finland stood out in 2003 with the highest indices in the people (3.247%) and prosperity (2.076%) pillars, while Ireland led in the planet pillar (2.026%), and Denmark excelled in partnership (1.445%) and peace (0.973%). By 2013 and 2023, Sweden had become the top performer in the people (13.828% and 15.736%), prosperity (8.414% and 9.939%), partnership (5.567% and 6.148%), and peace (3.849% and 4.008%) pillars, while Finland maintained leadership in the planet pillar (7.913% and 9.030%).

At the same time, the peace pillar remains the least achieved (around 4% in 2023), whereas the people pillar emerges as the most achieved (approximately 15% in 2023), suggesting different levels of progress across the sustainability dimensions.

Our results further show that, beyond the aforementioned top performers, Bulgaria, Cyprus, Estonia, Luxembourg, and Romania were efficient up to 2013, while Sweden has been efficient from 2004 onward. These trends highlight both structural consistency and emerging shifts in public sector performance over time.

In summary, there are marked disparities in how EU countries utilize public expenditure in pursuit of the SDGs. Higher efficiency appears to be correlated with stronger performance in sustainability outcomes.

In this context, public policies should prioritize optimizing the allocation of public funds rather than increasing expenditure indiscriminately. The study's findings demonstrate that economies which have implemented strategic reductions in public spending – particularly in areas such as public services, allocation, and redistribution – have achieved higher levels of efficiency and greater progress toward the Sustainable Development Goals (SDGs). This is evident in countries such as Ireland, Denmark, Finland, and Sweden.

Additionally, policy efforts should be directed toward strengthening the pillars of sustainable development that show lower levels of progress, particularly the peace and partnership pillars. This requires the design of targeted interventions that foster social cohesion, democratic governance, and international cooperation, with the aim of balancing progress across the various dimensions of the 2030 Agenda.

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Appendix A. Results of the DEA models based on min-max normalization criterion

Appendix A.1. DEA analysis between the Musgravian public spending and the 5 pillars of the SDGs using a principal component analysis

Table A1. Input-oriented DEA VRS technical efficiency scores for 2003, 2013, and 2023 (output: pca; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.864	16	LUX DNK IRL	1.000	1	AUT	0.787	22	IRL DNK SWE
Belgium	0.777	23	IRL LUX	0.819	26	FIN LVA DEU EST IRL	0.857	21	IRL DNK LVA LTU ITA
Bulgaria	1.000	1	BGR	1.000	1	BGR	1.000	1	BGR
Croatia	0.713	26	IRL EST ROU	0.868	23	LVA LUX EST ROU	1.000	1	HRV
Cyprus	1.000	1	CYP	1.000	1	CYP	0.767	23	BGR IRL ROU
Czech Republic	0.956	10	LUX EST IRL	0.961	17	LVA AUT EST IRL	0.709	25	IRL
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.965	9	DNK IRL	1.000	1	FIN	1.000	1	FIN
France	0.700	27	IRL	0.853	24	FIN DNK LTU ITA	1.000	1	FRA
Germany	0.776	24	IRL LUX EST	1.000	1	DEU	1.000	1	DEU
Greece	0.850	17	IRL CYP ROU	0.809	27	SVK BGR LUX ITA MLT	1.000	1	GRC
Hungary	0.784	21	IRL ROU	0.876	21	LTU MLT LVA LUX ROU	0.872	19	ROU IRL ITA
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.906	12	IRL	1.000	1	ITA	1.000	1	ITA
Latvia	0.966	8	IRL EST LUX	1.000	1	LVA	1.000	1	LVA
Lithuania	0.931	11	IRL EST ROU	1.000	1	LTU	1.000	1	LTU
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.695	26	IRL NLD DEU
Malta	0.883	14	IRL ROU	1.000	1	MLT	0.865	20	IRL ROU
Netherlands	0.779	22	IRL CYP ROU	0.926	20	IRL LTU SWE LUX	1.000	1	NLD
Poland	0.895	13	IRL	0.871	22	LTU BGR EST LUX CYP	0.760	24	BGR IRL
Portugal	0.810	19	IRL EST ROU	0.941	18	MLT DEU LTU BGR ITA	0.659	27	IRL ROU ITA
Romania	1.000	1	ROU	1.000	1	ROU	1.000	1	ROU
Slovak Republic	0.794	20	EST ROU	1.000	1	SVK	1.000	1	SVK
Slovenia	0.820	18	EST LUX IRL	0.849	25	IRL DEU LTU LUX EST	1.000	1	SVN
Spain	0.870	15	ROU IRL EST	0.939	19	IRL EST LTU LUX CYP	1.000	1	ESP
Sweden	0.730	25	LUX IRL	1.000	1	SWE	1.000	1	SWE
Average	0.880			0.952			0.925		
Countries on the frontier	7			16			18		
Max	1.000			1.000			1.000		
Min	0.700			0.809			0.659		

Notes: (1) We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003. (2) We carry out a Principal Component Analysis (PCA) to obtain the outputs for each period. For the period 1995-2003 we obtain 2 components with an eigenvalue greater than 1 (Kaiser criterion). For 2004-2013 we obtain 4 components with an eigenvalue greater than 1. For 2014-2023 we obtain 5 components with an eigenvalue greater than 1.

Table A2. Output-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (output: pca; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.955	9	DNK LUX	1.000	1	AUT	0.975	20	FIN DNK IRL ITA
Belgium	0.843	15	IRL LUX DNK	0.881	21	LVA FIN	0.979	19	FRA IRL DNK ITA
Bulgaria	1.000	1	BGR	1.000	1	BGR	1.000	1	BGR
Croatia	0.591	27	LUX DNK IRL	0.865	23	LVA	1.000	1	HRV
Cyprus	1.000	1	CYP	1.000	1	CYP	0.900	25	ITA HRV GRC IRL
Czech Republic	0.893	11	IRL EST LUX	0.956	17	IRL AUT EST	0.916	24	FIN ITA IRL SVK
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.995	8	DNK IRL	1.000	1	FIN	1.000	1	FIN
France	0.803	17	DNK IRL	0.861	24	LVA LTU FIN	1.000	1	FRA
Germany	0.866	14	DNK IRL	1.000	1	DEU	1.000	1	DEU
Greece	0.837	16	IRL LUX CYP	0.816	26	EST LTU LVA FIN	1.000	1	GRC
Hungary	0.724	23	DNK IRL LUX	0.773	27	FIN LVA	0.938	21	HRV BGR IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.751	20	IRL DNK	1.000	1	ITA	1.000	1	ITA
Latvia	0.735	22	IRL EST	1.000	1	LVA	1.000	1	LVA
Lithuania	0.699	25	IRL DNK	1.000	1	LTU	1.000	1	LTU
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.930	22	DEU DNK IRL
Malta	0.759	19	CYP LUX	1.000	1	MLT	0.865	27	IRL ITA ROU
Netherlands	0.880	12	LUX DNK IRL	0.902	19	EST SWE LUX IRL	1.000	1	NLD
Poland	0.750	21	IRL LUX	0.827	25	EST LVA FIN LTU	0.877	26	ITA SVK FIN IRL
Portugal	0.794	18	DNK IRL LUX	0.868	22	FIN LVA ITA EST	0.917	23	SVN ITA IRL GRC
Romania	1.000	1	ROU	1.000	1	ROU	1.000	1	ROU
Slovak Republic	0.684	26	DNK IRL	1.000	1	SVK	1.000	1	SVK
Slovenia	0.718	24	IRL DNK LUX	0.882	20	FIN LVA EST	1.000	1	SVN
Spain	0.869	13	IRL DNK	0.915	18	AUT EST IRL FIN	1.000	1	ESP
Sweden	0.905	10	IRL DNK	1.000	1	SWE	1.000	1	SWE
Average	0.854			0.946			0.974		
Countries on the frontier	7			16			18		
Max	1.000			1.000			1.000		
Min	0.591			0.773			0.865		

Notes: (1) We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003. (2) We carry out a Principal Component Analysis (PCA) to obtain the outputs for each period. For the period 1995-2003 we obtain 2 components with an eigenvalue greater than 1 (Kaiser criterion). For 2004-2013 we obtain 4 components with an eigenvalue greater than 1. For 2014-2023 we obtain 5 components with an eigenvalue greater than 1.

Appendix A.2. DEA analysis between the Musgravian public spending and the 5 pillars of the SDGs using a classification based on the definition of the targets

Alternatively, we consider the textual information provided in the Metadata section of the SDG targets available in Eurostat, regarding the description of each target. In a second phase, we compile a dictionary of terms for each target. Subsequently, using sentiment analysis techniques[3], we carry out a word count for each definition, excluding words that do not contribute meaning. The aim of this process is to establish a weighted ranking of the SDGs according to the five pillars: people, planet, peace, partnership and prosperity. The words considered in the analysis for each pillar are presented in Table A3.

Table A3. Words considered in each pillar

People	***Prosperity***	***Planet***	***Peace***	***Partnership***
Anthropogenic	Abundance	Consumption	Distribution	Collaboration
Citizenship	Attainment	Emissions	Free	Community
Consumers	Development	Energies	Government	Connection
Equality	Earnings	Environment	Inclusion	Contribution
Goods	Economic	Global	Interventions	Council
Households	Efficiency	Life	Judge	Countries
Individuals	Expectancy	Oxygen	Management	Group
Inequalities	Growth	Pollution	Regulation	Members
People	Health	Production	Rights	Organization
Persons	Income	Species	Safety	Partners
Poverty	Prosperity	Water	Settlement	Relationships
Poverty	Social	Weather	Treatment	States
Residents	Welfare	World	Violence	Union

From these words, we derive different weights for each SDG by calculating the relative frequency of these words in the different definitions of the targets of each SDG. In Figure A1 we include weights obtained from our own classification of the target definitions and those obtained by Tremblay et al. (2020). Both classifications highlight the significance of the people pillar across goals 1, 3, 4, 5, and 10. However, in SDG number 2, our classification emphasizes the importance of the planet pillar, contrasting with Tremblay et al. (2020)'s classification, which places greater emphasis on the people pillar. The planet pillar holds more prominence in goals 6, 7, 11, 12, 13, 14, and 15. The peace pillar is significant in goals 5 and 16, while prosperity and partnership pillars are more pronounced in goals 8, 9, 10, and 17.

[3] For more information see Pawar, A. B., Jawale, M. A., & Kyatanavar, D. N. (2016). Fundamentals of sentiment analysis: concepts and methodology. *Sentiment analysis and ontology engineering: An environment of computational intelligence*, 25-48.

Figure A1. Relative distribution of the 5 pillars among the 17 SDGs

Tremblay et al. (2020) *Metadata of the targets*

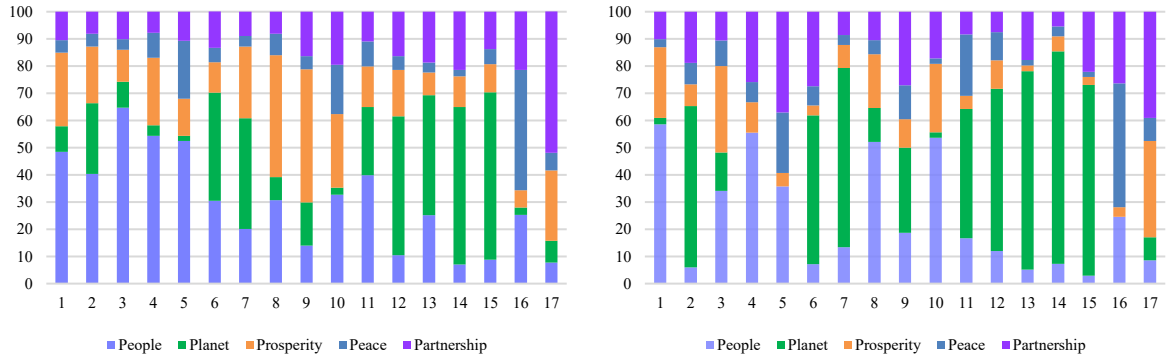

Table A4. Input-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (output: people, planet, prosperity, partnership and peace; input: redistribution, allocation, general public services, private activities government spending)

	2003	Rank	Peers	2013	Rank	Peers	2023	Rank	Peers
Austria	1.000	1	AUT	1.000	1	AUT	1.000	1	AUT
Belgium	0.862	20	IRL FIN DNK	0.826	26	LTU SWE LUX CYP IRL	0.565	25	CZE IRL
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.799	17	IRL
Croatia	0.714	27	IRL EST ROU	0.844	25	IRL ROU EST LUX	0.656	21	IRL
Cyprus	1.000	1	CYP	1.000	1	CYP	0.734	19	IRL
Czech Republic	1.000	1	CZE	1.000	1	CZE	1.000	1	CZE
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	0.937	10	IRL SWE NLD
Finland	1.000	1	FIN	1.000	1	FIN	1.000	1	FIN
France	0.728	26	DNK IRL FIN	0.861	23	DNK SWE SVK LTU CYP DEU	0.515	27	IRL
Germany	0.829	21	IRL FIN LUX	1.000	1	DEU	0.834	16	IRL SWE CZE
Greece	0.917	15	IRL ROU	0.817	27	SVK IRL LTU CYP BGR	0.585	24	IRL
Hungary	0.784	25	ROU IRL	0.852	24	IRL LUX CYP ROU BGR	0.746	18	IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.909	16	IRL LVA	1.000	1	ITA	0.537	26	IRL
Latvia	1.000	1	LVA	1.000	1	LVA	0.846	15	FIN IRL
Lithuania	0.931	13	IRL ROU EST	1.000	1	LTU	0.911	11	IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	1.000	1	LUX
Malta	0.883	19	IRL ROU	0.984	17	CYP LUX LTU BGR	0.848	14	IRL
Netherlands	0.920	14	LUX DNK IRL	0.969	19	EST SWE LTU DEU LUX	1.000	1	NLD
Poland	0.895	18	IRL	0.971	18	SWE CYP IRL SVK	0.890	12	IRL DNK
Portugal	0.810	24	IRL EST ROU	0.961	21	SVK CYP DNK DEU ITA	0.599	23	IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.866	13	IRL
Slovak Republic	0.816	23	EST IRL ROU	1.000	1	SVK	1.000	1	SVK
Slovenia	0.820	22	EST IRL LUX	0.906	22	SWE SVK IRL LUX	0.733	20	IRL CZE DNK
Spain	0.904	17	CYP IRL ROU	0.968	20	SVK BGR EST LUX IRL CYP ROU	0.608	22	IRL
Sweden	1.000	1	SWE	1.000	1	SWE	1.000	1	SWE
Average	0.916			0.961			0.823		
Countries on the frontier	12			16			9		
Max	1.000			1.000			1.000		
Min	0.714			0.817			0.515		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Table A5. Output-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (output: people, planet, prosperity, partnership and peace; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	1.000	1	AUT	1.000	1	AUT	1.000	1	AUT
Belgium	0.957	17	FIN LVA IRL	0.895	23	SWE IRL	0.888	20	IRL FIN SWE
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.823	25	FIN IRL
Croatia	0.862	23	AUT LVA IRL	0.823	26	SWE IRL LVA	0.982	12	IRL DNK SVK
Cyprus	1.000	1	CYP	1.000	1	CYP	0.877	22	IRL SWE
Czech Republic	1.000	1	CZE	1.000	1	CZE	1.000	1	CZE
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	0.982	12	IRL SWE FIN
Finland	1.000	1	FIN	1.000	1	FIN	1.000	1	FIN
France	0.917	21	IRL FIN SWE LVA	0.855	24	SWE	0.894	17	SWE DNK
Germany	0.967	16	AUT FIN IRL	1.000	1	DEU	0.941	16	IRL CZE SWE
Greece	0.975	13	DNK IRL	0.834	25	IRL SWE	0.808	26	FIN IRL
Hungary	0.873	22	AUT LVA IRL	0.821	27	IRL CZE SWE LUX	0.890	19	CZE DNK IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.975	13	AUT LVA IRL	1.000	1	ITA	0.879	21	FIN IRL
Latvia	1.000	1	LVA	1.000	1	LVA	0.978	14	FIN IRL
Lithuania	0.935	19	IRL FIN LVA	1.000	1	LTU	0.944	15	FIN IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	1.000	1	LUX
Malta	0.629	27	AUT LVA IRL	0.905	22	SVK LTU CYP LUX BGR	0.828	24	IRL LUX DNK
Netherlands	0.974	15	LUX IRL DNK	0.971	18	SWE LUX CZE	1.000	1	NLD
Poland	0.821	25	AUT LVA IRL	0.977	17	SWE CYP IRL SVK	0.994	10	IRL DNK SVK
Portugal	0.832	24	IRL FIN	0.931	20	SWE SVK CYP DNK	0.893	18	IRL DNK SVK
Romania	1.000	1	ROU	1.000	1	ROU	0.762	27	IRL FIN
Slovak Republic	0.925	20	AUT LVA IRL	1.000	1	SVK	1.000	1	SVK
Slovenia	0.803	26	DNK IRL	0.931	20	SWE IRL	0.983	11	IRL DNK SVK
Spain	0.956	18	FIN IRL LVA	0.955	19	ROU EST IRL CYP CZE	0.874	23	IRL DNK SVK
Sweden	1.000	1	SWE	1.000	1	SWE	1.000	1	SWE
Average	0.941			0.959			0.934		
Countries on the frontier	12			16			9		
Max	1.000			1.000			1.000		
Min	0.629			0.821			0.762		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Appendix A.3. Number of efficient countries by the three methodologies

Table A6. Efficient countries by different classification, input-oriented

	Methodology 1			*Methodology 2*			*Methodology 3*			***Countries***
	2003	*2013*	*2023*	*2003*	*2013*	*2023*	*2003*	*2013*	*2023*	
Austria		1.000			1.000		1.000	1.000	1.000	5
Belgium										0
Bulgaria	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Croatia						1.000				1
Cyprus	1.000	1.000		1.000	1.000		1.000	1.000		6
Czech Republic							1.000	1.000	1.000	3
Denmark	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Estonia	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Finland	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	8
France						1.000				1
Germany					1.000	1.000		1.000		3
Greece						1.000				1
Hungary										0
Ireland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Italy		1.000			1.000	1.000		1.000		4
Latvia		1.000			1.000	1.000	1.000	1.000		5
Lithuania		1.000			1.000	1.000		1.000		4
Luxembourg	1.000	1.000		1.000	1.000		1.000	1.000	1.000	7
Malta					1.000					1
Netherlands			1.000			1.000			1.000	3
Poland										0
Portugal										0
Romania	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Slovak Republic					1.000	1.000		1.000	1.000	4
Slovenia						1.000				1
Spain						1.000				1
Sweden		1.000	1.000		1.000	1.000	1.000	1.000	1.000	7
Countries	8	13	5	7	16	18	12	16	9	

Table A7. Efficient countries by different classification, output-oriented perspective

	Methodology 1			*Methodology 2*			*Methodology 3*			***Countries***
	2003	*2013*	*2023*	*2003*	*2013*	*2023*	*2003*	*2013*	*2023*	
Austria		1.000			1.000		1.000	1.000	1.000	5
Belgium										0
Bulgaria	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Croatia						1.000				1
Cyprus	1.000	1.000		1.000	1.000		1.000	1.000		6
Czech Republic							1.000	1.000	1.000	3
Denmark	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Estonia	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Finland	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	8
France						1.000				1
Germany					1.000	1.000		1.000		3
Greece						1.000				1
Hungary										0
Ireland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Italy		1.000			1.000	1.000		1.000		4
Latvia		1.000			1.000	1.000	1.000	1.000		5
Lithuania		1.000			1.000	1.000		1.000		4
Luxembourg	1.000	1.000		1.000	1.000		1.000	1.000	1.000	7
Malta					1.000					1
Netherlands			1.000			1.000			1.000	3
Poland										0
Portugal										0
Romania	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Slovak Republic					1.000	1.000		1.000	1.000	4
Slovenia						1.000				1
Spain						1.000				1
Sweden		1.000	1.000		1.000	1.000	1.000	1.000	1.000	7
Countries	8	13	5	7	16	18	12	16	9	

Appendix B. Results of the DEA models based on average normalization criterion

Appendix B.1. DEA analysis between the Musgravian public spending and the 5 pillars of the SDGs using Methodology 1 based on Tremblay et al., (2020)

Table B1. Input-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.836	17	LUX IRL	0.812	25	LUX	0.668	16	IRL MLT
Belgium	0.789	22	IRL DNK EST LUX	0.781	27	BGR LUX LTU	0.512	27	MLT IRL
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.803	8	IRL MLT
Croatia	0.713	26	EST ROU IRL	0.840	21	EST LUX ROU	0.657	17	MLT IRL
Cyprus	1.000	1	CYP	0.966	10	LTU MLT BGR	0.740	12	MLT IRL
Czech Republic	0.920	12	EST IRL ROU	0.901	17	LUX EST LTU ROU	0.714	13	IRL EST
Denmark	1.000	1	DNK	1.000	1	DNK	0.948	4	MLT IRL
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.818	19	DNK LUX IRL	0.933	14	DNK LUX LTU	0.617	19	MLT IRL
France	0.700	27	IRL	0.818	23	DNK ITA LTU	0.515	26	IRL
Germany	0.776	24	LUX EST IRL	0.985	9	DNK LUX LTU	0.599	23	EST IRL
Greece	0.843	16	IRL CYP ROU LVA	0.782	26	LTU LUX BGR	0.585	24	MLT IRL
Hungary	0.784	23	IRL ROU	0.848	20	LUX ROU BGR	0.747	11	MLT IRL
Ireland	1.000	1	IRL	0.960	11	LUX LTU ROU EST	1.000	1	IRL
Italy	0.906	13	IRL	1.000	1	ITA	0.537	25	IRL
Latvia	1.000	1	LVA	0.956	12	MLT EST LUX ROU	0.768	9	MLT IRL
Lithuania	0.947	10	LVA LUX ROU IRL EST	1.000	1	LTU	0.928	5	EST IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.702	14	IRL MLT EST
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	0.891	14	EST DNK LVA	0.825	22	ROU MLT LTU LUX EST	0.859	7	EST IRL
Poland	0.921	11	IRL DNK EST	0.863	19	LTU BGR LUX	0.765	10	EST IRL
Portugal	0.810	20	EST ROU IRL	0.913	16	DNK LTU LUX	0.600	22	MLT IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.866	6	IRL
Slovak Republic	0.794	21	ROU EST	0.945	13	LTU BGR ROU LUX	0.685	15	MLT IRL
Slovenia	0.820	18	EST IRL LUX	0.815	24	LUX LTU EST	0.607	21	EST IRL
Spain	0.868	15	IRL EST ROU	0.895	18	LUX ROU LTU BGR	0.608	20	IRL
Sweden	0.735	25	DNK IRL LUX	0.931	15	LUX LTU DNK	0.622	18	IRL EST
Average	0.884			0.917			0.728		
Countries on the frontier	9			8			3		
Max	1.000			1.000			1.000		
Min	0.700			0.781			0.512		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Table B2. Output-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (outputs: people, planet, partnership, peace and prosperity pillars; inputs: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.073	19	DNK LUX EST	0.061	14	MLT LUX	0.089	12	MLT IRL
Belgium	0.162	14	EST LVA DNK	0.022	22	MLT	0.049	22	MLT
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.076	13	MLT IRL EST
Croatia	0.041	23	EST	0.024	20	MLT EST	0.051	21	MLT
Cyprus	1.000	1	CYP	0.074	12	MLT BGR LTU	0.144	10	MLT IRL
Czech Republic	0.038	27	EST DNK	0.028	19	MLT EST	0.070	15	MLT EST
Denmark	1.000	1	DNK	1.000	1	DNK	0.885	4	MLT IRL
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.249	13	DNK LUX EST	0.071	13	DNK MLT LUX	0.132	11	MLT IRL
France	0.041	23	DNK EST	0.017	26	MLT	0.037	27	MLT IRL
Germany	0.057	21	DNK EST LUX	0.056	15	MLT LTU DNK LUX	0.068	17	MLT IRL
Greece	0.161	15	EST LVA DNK	0.018	25	MLT	0.038	26	MLT IRL
Hungary	0.044	22	DNK LVA EST LUX	0.014	27	MLT	0.039	25	MLT
Ireland	1.000	1	IRL	0.075	11	MLT EST LUX	1.000	1	IRL
Italy	0.100	17	DNK EST IRL	1.000	1	ITA	0.048	23	MLT IRL
Latvia	1.000	1	LVA	0.198	9	MLT EST ROU	0.179	7	EST MLT
Lithuania	0.498	11	EST IRL LVA LUX	1.000	1	LTU	0.300	6	MLT IRL EST
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.155	9	IRL MLT
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	0.788	10	EST DNK	0.169	10	MLT EST	0.475	5	MLT EST IRL
Poland	0.344	12	IRL DNK EST	0.021	23	MLT EST	0.159	8	EST MLT IRL
Portugal	0.040	26	DNK EST LUX LVA	0.024	20	MLT ITA	0.070	15	MLT IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.046	24	MLT IRL
Slovak Republic	0.041	23	EST	0.048	17	MLT LTU EST	0.055	20	IRL MLT
Slovenia	0.093	18	EST DNK LUX	0.040	18	MLT EST	0.063	18	MLT IRL
Spain	0.067	20	DNK EST LUX LVA	0.021	23	MLT EST	0.056	19	MLT IRL
Sweden	0.111	16	EST DNK	0.049	16	MLT DNK LUX LTU	0.073	14	MLT IRL
Average	0.443			0.334			0.235		
Countries on the frontier	9			8			3		
Max	1.000			1.000			1.000		
Min	0.038			0.014			0.037		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Appendix B.2. DEA analysis between the Musgravian public spending and the 5 pillars of the SDGs using Methodology 2 based on Principal Component Analysis

Table B3. Input-oriented DEA VRS technical efficiency scores for 2003, 2013, and 2023 (output: pca; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.892	16	LUX DNK MLT IRL	0.980	17	LUX IRL MLT	1.000	1	AUT
Belgium	0.823	19	IRL BGR DNK MLT	0.848	25	LUX NLD SVN MLT	0.753	24	DNK EST IRL DEU LTU
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.941	18	IRL LTU EST
Croatia	0.713	27	EST IRL ROU	0.847	26	MLT EST LUX ROU IRL	1.000	1	HRV
Cyprus	1.000	1	CYP	1.000	1	CYP	0.802	20	IRL MLT EST
Czech Republic	1.000	1	CZE	0.968	18	NLD EST ROU LUX MLT	0.827	19	IRL MLT NLD
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.870	17	DNK EST LUX IRL	1.000	1	FIN	1.000	1	FIN
France	0.732	26	IRL LVA BGR	0.858	24	MLT LUX LTU ITA DNK	1.000	1	FRA
Germany	0.776	24	IRL EST LUX	0.998	16	MLT LTU LUX DNK	1.000	1	DEU
Greece	0.921	15	ROU MLT IRL	0.796	27	BGR MLT LUX ITA CYP	0.700	27	IRL EST LTU
Hungary	0.801	22	ROU LVA IRL LUX	0.865	23	MLT LUX ROU EST	0.778	22	MLT EST IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.940	14	DNK IRL MLT BGR	1.000	1	ITA	1.000	1	ITA
Latvia	1.000	1	LVA	1.000	1	LVA	0.969	17	IRL LTU EST
Lithuania	0.958	13	LVA EST IRL ROU LUX	1.000	1	LTU	1.000	1	LTU
Luxembourg	1.000	1	LUX	1.000	1	LUX	1.000	1	LUX
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	0.998	12	IRL MLT DNK EST	1.000	1	NLD	1.000	1	NLD
Poland	1.000	1	POL	0.882	22	NLD BGR LUX LTU CYP	0.767	23	EST LTU IRL
Portugal	0.817	21	LVA IRL LUX ROU	0.931	21	MLT LTU LUX DNK ITA	0.799	21	IRL DNK LTU EST
Romania	1.000	1	ROU	1.000	1	ROU	0.994	16	IRL EST
Slovak Republic	0.798	23	EST IRL ROU	0.965	19	EST LUX LTU MLT BGR	0.705	25	EST IRL MLT
Slovenia	0.820	20	EST IRL LUX	1.000	1	SVN	1.000	1	SVN
Spain	0.868	18	EST IRL CYP ROU	0.951	20	NLD LUX MLT IRL ROU	0.705	25	IRL LTU MLT
Sweden	0.757	25	DNK IRL MLT LUX	1.000	1	SWE	1.000	1	SWE
Average	0.907			0.959			0.916		
Countries on the frontier	11			15			15		
Max	1.000			1.000			1.000		
Min	0.713			0.796			0.700		

Notes: (1) We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003. (2) We carry out a Principal Component Analysis (PCA) to obtain the outputs for each period. For the period 1995-2003 we obtain 4 components with an eigenvalue greater than 1 (Kaiser criterion). For 2004-2013 we obtain 6 components with an eigenvalue greater than 1. For 2014-2023 we obtain 6 components with an eigenvalue greater than 1.

Table B4. Output-oriented DEA VRS technical efficiency scores for 2003, 2013, and 2023 (output: pca; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.981	14	DNK IRL MLT LUX	0.982	16	LUX IRL DNK MLT	1.000	1	AUT
Belgium	0.941	15	DNK MLT IRL	0.914	19	FIN NLD MLT SVN	0.977	18	DNK ITA LTU DEU
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.977	18	IRL LTU EST
Croatia	0.866	27	DNK EST IRL MLT	0.702	27	NLD EST MLT	1.000	1	HRV
Cyprus	1.000	1	CYP	1.000	1	CYP	0.912	23	IRL MLT EST LTU
Czech Republic	1.000	1	CZE	0.934	18	NLD MLT EST LUX	0.867	24	EST LUX NLD IRL
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.939	16	EST DNK IRL	1.000	1	FIN	1.000	1	FIN
France	0.882	25	DNK MLT IRL	0.831	23	ITA MLT NLD EST	1.000	1	FRA
Germany	0.912	21	DNK IRL MLT	0.980	17	LUX LTU MLT DNK	1.000	1	DEU
Greece	0.989	13	MLT DNK IRL	0.790	25	EST NLD MLT LUX	0.951	22	LTU EST ITA
Hungary	0.895	22	DNK EST MLT IRL	0.820	24	DNK MLT EST	0.811	27	EST LTU DNK IRL
Ireland	1.000	1	IRL	1.000	1	IRL	1.000	1	IRL
Italy	0.937	18	DNK BGR IRL MLT	1.000	1	ITA	1.000	1	ITA
Latvia	1.000	1	LVA	1.000	1	LVA	0.988	17	EST LTU IRL
Lithuania	0.938	17	DNK EST MLT LUX	1.000	1	LTU	1.000	1	LTU
Luxembourg	1.000	1	LUX	1.000	1	LUX	1.000	1	LUX
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	1.000	1	IRL MLT DNK EST	1.000	1	NLD	1.000	1	NLD
Poland	1.000	1	POL	0.786	26	NLD LTU EST MLT	0.851	26	FIN EST HRV IRL
Portugal	0.915	20	IRL EST DNK MLT	0.867	22	EST DNK ITA MLT	0.959	20	LTU IRL DEU DNK
Romania	1.000	1	ROU	1.000	1	ROU	0.992	16	IRL EST
Slovak Republic	0.894	23	DNK EST MLT IRL	0.911	20	NLD LUX LTU EST	0.867	24	EST LTU IRL MLT
Slovenia	0.867	26	IRL EST MLT DNK	1.000	1	SVN	1.000	1	SVN
Spain	0.930	19	MLT DNK EST IRL	0.907	21	MLT NLD ROU IRL	0.956	21	DEU LTU MLT
Sweden	0.891	24	DNK IRL MLT	1.000	1	SWE	1.000	1	SWE
Average	0.955			0.942			0.967		
Countries on the frontier	12			15			15		
Max	1.000			1.000			1.000		
Min	0.866			0.702			0.811		

Notes: (1) We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003. (2) We carry out a Principal Component Analysis (PCA) to obtain the outputs for each period. For the period 1995-2003 we obtain 4 components with an eigenvalue greater than 1 (Kaiser criterion). For 2004-2013 we obtain 6 components with an eigenvalue greater than 1. For 2014-2023 we obtain 6 components with an eigenvalue greater than 1.

Appendix B.3. DEA analysis between the Musgravian public spending and the 5 pillars of the SDGs using Methodology 2 based on the metadata definition of the targets

Table B5. Input-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (output: people, planet, prosperity, partnership and peace; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.836	17	LUX IRL	0.812	25	LUX	0.683	16	DNK IRL
Belgium	0.801	21	IRL MLT DNK LUX	0.781	27	LTU LUX BGR	0.516	26	EST IRL
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.862	9	EST IRL MLT
Croatia	0.713	26	IRL EST ROU	0.840	22	ROU EST LUX	0.683	16	MLT IRL
Cyprus	1.000	1	CYP	0.970	11	EST BGR LTU MLT	0.769	12	MLT IRL
Czech Republic	0.920	13	EST IRL ROU	0.901	18	EST ROU LTU LUX	0.715	14	EST MLT IRL
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.819	19	DNK IRL LUX	0.933	15	DNK LUX LTU	0.659	18	DNK IRL EST
France	0.700	27	IRL	0.818	23	ITA DNK LTU	0.515	27	IRL
Germany	0.776	24	IRL EST LUX	0.985	10	LUX DNK LTU	0.601	22	EST IRL
Greece	0.852	16	IRL MLT ROU CYP	0.782	26	MLT LTU LUX BGR	0.585	24	IRL MLT
Hungary	0.784	23	IRL ROU	0.848	21	ROU LUX BGR	0.749	13	MLT IRL
Ireland	1.000	1	IRL	0.960	12	LUX LTU ROU EST	1.000	1	IRL
Italy	0.906	14	IRL	1.000	1	ITA	0.537	25	IRL
Latvia	1.000	1	LVA	0.986	9	EST LUX ROU	0.824	10	EST MLT IRL
Lithuania	0.947	10	LVA IRL ROU EST LUX	1.000	1	LTU	0.929	5	EST MLT IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.927	6	MLT IRL EST
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	0.922	12	MLT DNK EST LVA	0.957	13	EST DNK LTU	0.864	8	IRL EST
Poland	0.932	11	IRL DNK	0.863	20	LTU LUX BGR	0.776	11	IRL EST MLT
Portugal	0.810	20	ROU IRL EST	0.913	17	DNK LUX LTU	0.600	23	MLT IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.871	7	IRL MLT
Slovak Republic	0.794	22	EST ROU	0.945	14	LUX LTU ROU BGR	0.695	15	IRL MLT
Slovenia	0.820	18	IRL LUX EST	0.815	24	LTU LUX EST	0.610	20	EST IRL
Spain	0.868	15	EST ROU IRL	0.895	19	ROU LUX BGR LTU	0.608	21	IRL
Sweden	0.739	25	DNK IRL LUX	0.931	16	LUX LTU DNK	0.626	19	EST IRL
Average	0.887			0.924			0.748		
Countries on the frontier	9			8			4		
Max	1.000			1.000			1.000		
Min	0.700			0.781			0.515		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Table B6. Output-oriented DEA VRS technical efficiency scores for 2003, 2013 and 2023 (output: people, planet, prosperity, partnership and peace; input: redistribution, allocation, general public services, private activities government spending)

	2003	*Rank*	*Peers*	*2013*	*Rank*	*Peers*	*2023*	*Rank*	*Peers*
Austria	0.218	18	LUX IRL EST	0.533	14	EST DNK LUX	0.641	6	EST MLT IRL
Belgium	0.241	16	DNK MLT LVA	0.356	19	EST DNK	0.305	25	EST MLT
Bulgaria	1.000	1	BGR	1.000	1	BGR	0.399	18	EST MLT IRL
Croatia	0.066	27	EST	0.212	27	EST	0.610	9	MLT EST
Cyprus	1.000	1	CYP	0.683	11	LTU EST BGR	0.545	10	EST IRL
Czech Republic	0.086	25	EST LUX	0.314	22	EST LUX DNK	0.420	15	EST MLT
Denmark	1.000	1	DNK	1.000	1	DNK	1.000	1	DNK
Estonia	1.000	1	EST	1.000	1	EST	1.000	1	EST
Finland	0.312	13	DNK LUX EST	0.600	13	LUX EST DNK	0.527	11	EST MLT IRL
France	0.104	23	EST IRL	0.325	21	EST DNK	0.300	26	EST MLT
Germany	0.183	19	EST IRL LUX	0.674	12	EST DNK LUX LTU	0.467	13	EST MLT IRL
Greece	0.267	15	EST DNK MLT LVA	0.231	26	EST	0.231	27	EST
Hungary	0.095	24	DNK EST LUX	0.259	24	EST LUX DNK	0.316	23	EST MLT
Ireland	1.000	1	IRL	0.506	16	EST LUX	1.000	1	IRL
Italy	0.312	13	EST IRL	1.000	1	ITA	0.350	21	EST IRL
Latvia	1.000	1	LVA	0.785	10	EST LUX ROU	0.451	14	EST MLT
Lithuania	0.511	11	LVA ROU MLT IRL	1.000	1	LTU	0.640	7	EST IRL
Luxembourg	1.000	1	LUX	1.000	1	LUX	0.940	5	MLT EST IRL
Malta	1.000	1	MLT	1.000	1	MLT	1.000	1	MLT
Netherlands	0.882	10	DNK EST MLT	0.962	9	EST DNK	0.625	8	EST DNK IRL
Poland	0.430	12	EST DNK IRL	0.278	23	EST LTU DNK	0.376	19	EST MLT IRL
Portugal	0.107	22	DNK EST LUX IRL	0.332	20	DNK EST LTU	0.350	21	EST MLT IRL
Romania	1.000	1	ROU	1.000	1	ROU	0.308	24	EST IRL MLT
Slovak Republic	0.077	26	EST	0.399	17	EST DNK LTU	0.400	17	MLT IRL EST
Slovenia	0.224	17	EST IRL LUX	0.386	18	EST DNK LUX	0.516	12	IRL EST MLT
Spain	0.136	21	EST LUX IRL	0.252	25	EST LUX DNK	0.372	20	EST MLT IRL
Sweden	0.163	20	EST LUX DNK IRL	0.529	15	LUX EST DNK	0.407	16	EST MLT IRL
Average	0.497			0.615			0.537		
Countries on the frontier	9			8			4		
Max	1.000			1.000			1.000		
Min	0.066			0.212			0.231		

Note: We consider the following periods: 1995-2003, 2004-2013, and 2014-2023. Each year shows the simple average of the indicators in each period, e.g. 2003 is the result of the average of the variables considered in the period 1995-2003.

Appendix B.4. Number of efficient countries by the three methodologies

Table B7. Efficient countries by different classification, input-oriented

	Tremblay			*PCA*			*Metadata*			*Countries*
	2003	*2013*	*2023*	*2003*	*2013*	*2023*	*2003*	*2013*	*2023*	
Austria						1.000				1
Belgium										0
Bulgaria	1.000	1.000		1.000	1.000		1.000	1.000		6
Croatia						1.000				1
Cyprus	1.000			1.000	1.000		1.000			4
Czech Republic				1.000						1
Denmark	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	8
Estonia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Finland					1.000	1.000				2
France						1.000				1
Germany						1.000				1
Greece										0
Hungary										0
Ireland	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	8
Italy		1.000			1.000	1.000				3
Latvia	1.000			1.000	1.000		1.000			4
Lithuania		1.000			1.000	1.000		1.000		4
Luxembourg	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Malta	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Netherlands					1.000	1.000				2
Poland				1.000						1
Portugal										0
Romania	1.000	1.000		1.000	1.000		1.000	1.000		6
Slovak Republic										0
Slovenia					1.000	1.000				2
Spain										0
Sweden					1.000	1.000				2
Countries	9	8	3	11	15	15	9	8	4	

Table B8. Efficient countries by different classification, output-oriented

	Tremblay			*PCA*			*Metadata*			*Countries*
	2003	*2013*	*2023*	*2003*	*2013*	*2023*	*2003*	*2013*	*2023*	
Austria						1.000				1
Belgium										0
Bulgaria	1.000	1.000		1.000	1.000		1.000	1.000		6
Croatia						1.000				1
Cyprus	1.000			1.000	1.000		1.000			4
Czech Republic				1.000						1
Denmark	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	8
Estonia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Finland					1.000	1.000				2
France						1.000				1
Germany						1.000				1
Greece										0
Hungary										0
Ireland	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	8
Italy		1.000			1.000	1.000				3
Latvia	1.000			1.000	1.000		1.000			4
Lithuania		1.000			1.000	1.000		1.000		4
Luxembourg	1.000	1.000		1.000	1.000	1.000	1.000	1.000		7
Malta	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9
Netherlands				1.000	1.000	1.000				3
Poland				1.000						1
Portugal										0
Romania	1.000	1.000		1.000	1.000		1.000	1.000		6
Slovak Republic										0
Slovenia					1.000	1.000				2
Spain										0
Sweden					1.000	1.000				2
Countries	9	8	3	12	15	15	9	8	4	